UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

The Digital Forest

Geospatial Technologies in Urban Forest Management

Justin Morgenroth
New Zealand School of Forestry
University of Canterbury

Why Measure a Tree?

- Determine annual growth
- Determine value
  - CTLA
  - STEM
- Find champions

  = Trunk Circumference

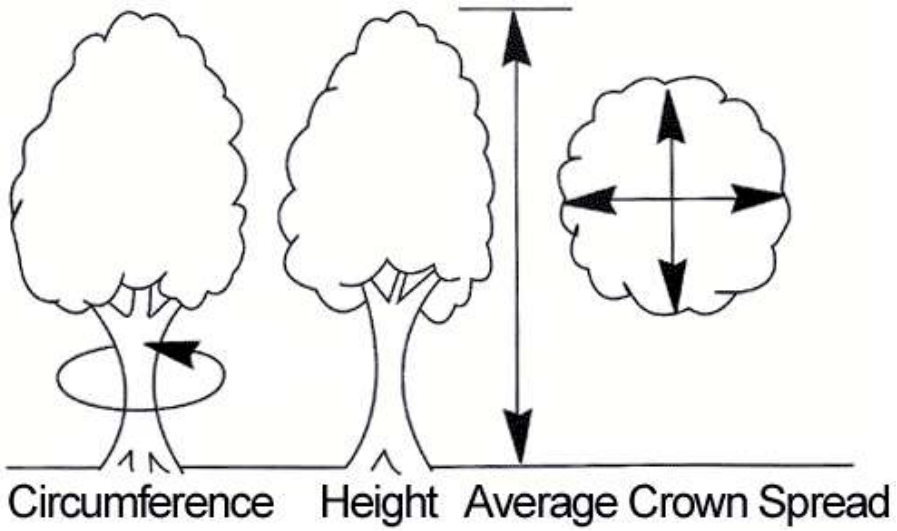
  + Height

  + ¼ Avg Crown Spread

Photo credit: Brad Cadwallader

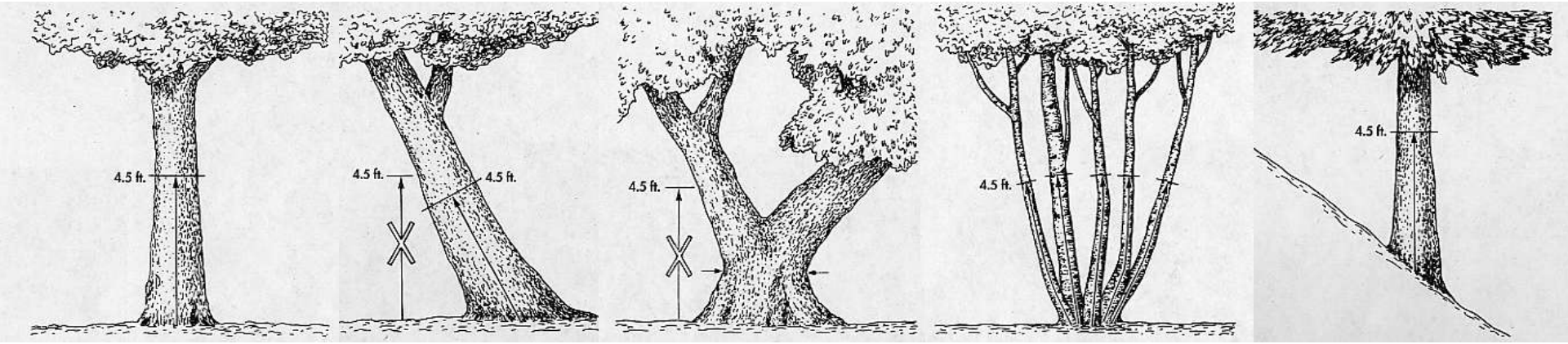
How do we measure trees?

- Diameter (DBH)
  - Tape, calipers
- Height
  - Height pole, clinometer, vertex, tape drop
- Crown diameter and depth
  - Tape measure
- We've been measuring this way for a long time!



Problems with Girth

- Simple measures can still be complex
  - Because trees are complex
- Even DBH not universally accepted



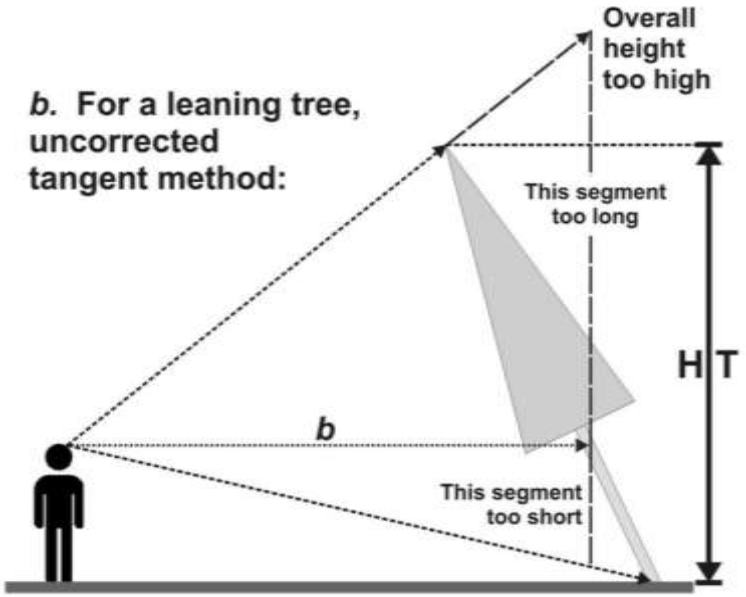
- Tape method converts circumference to diameter
  - Assumes a circular tree

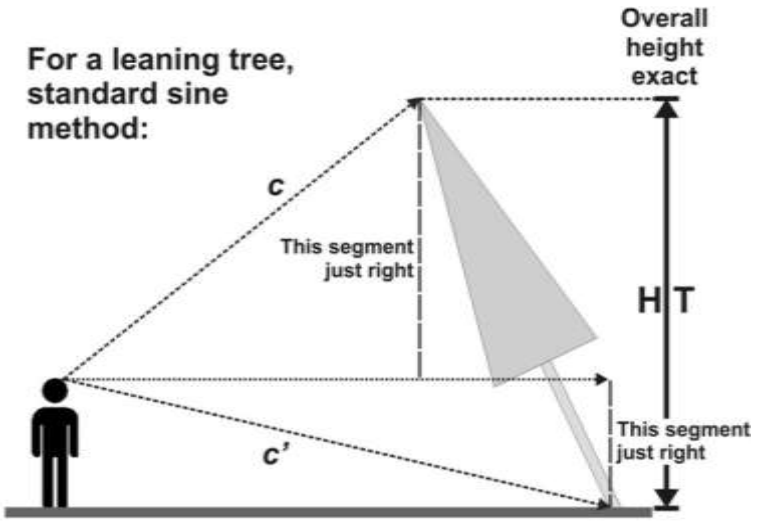
Problems with Height

- Finding ‘true’ top of tree is challenge
- Estimation methods applied incorrectly

$$\mathrm{HT} = b \times \tan(A) + b' \times \tan(A')$$

$$\mathrm{HT} = c \times \sin(A) + c' \times \sin(A')$$





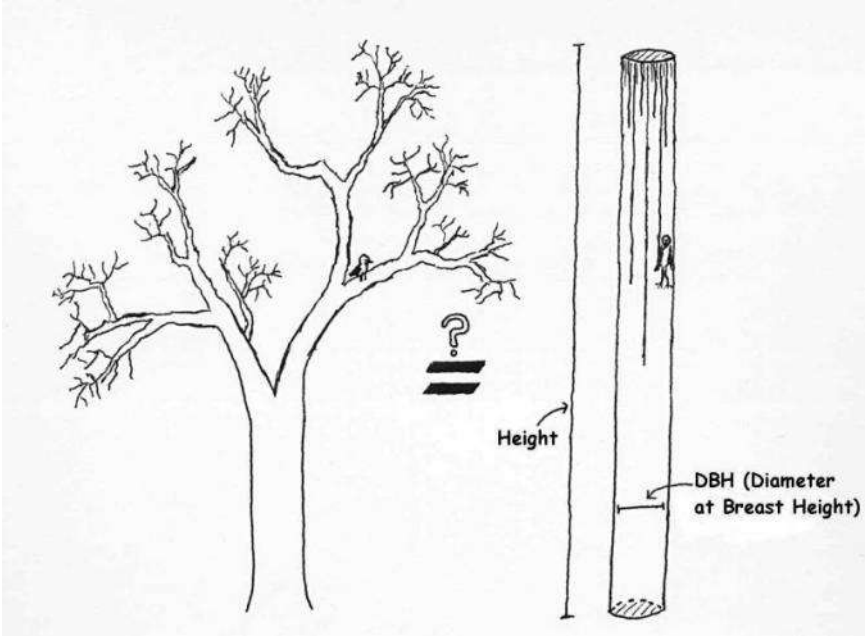
Problems with Current Techniques

Photo credit: Brad Cadwallader

- ‘False’ champions
- ENTS shows examples of errors of up to 54%!
- 58m Hickory actually 37.5m
- 54.5m Maple actually 36.5m
- 45m Ginkgo actually 30m

Problems with Current Techniques

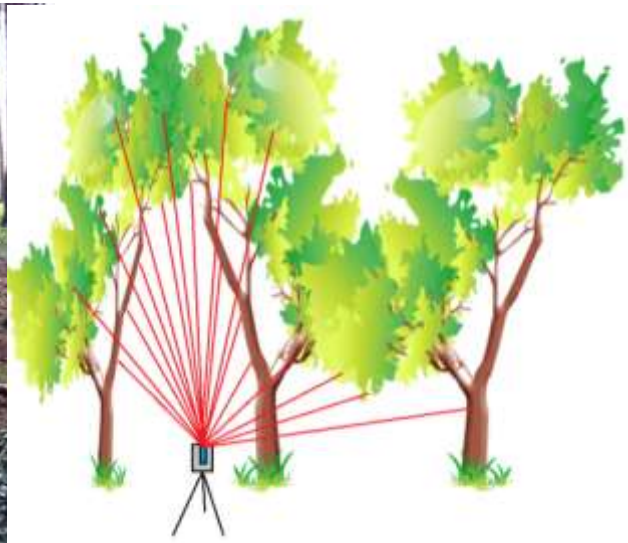
- Benefits rely on total volume:
  - Carbon sequestration, air pollution removal, climate moderation



- Volume only by allometric equations

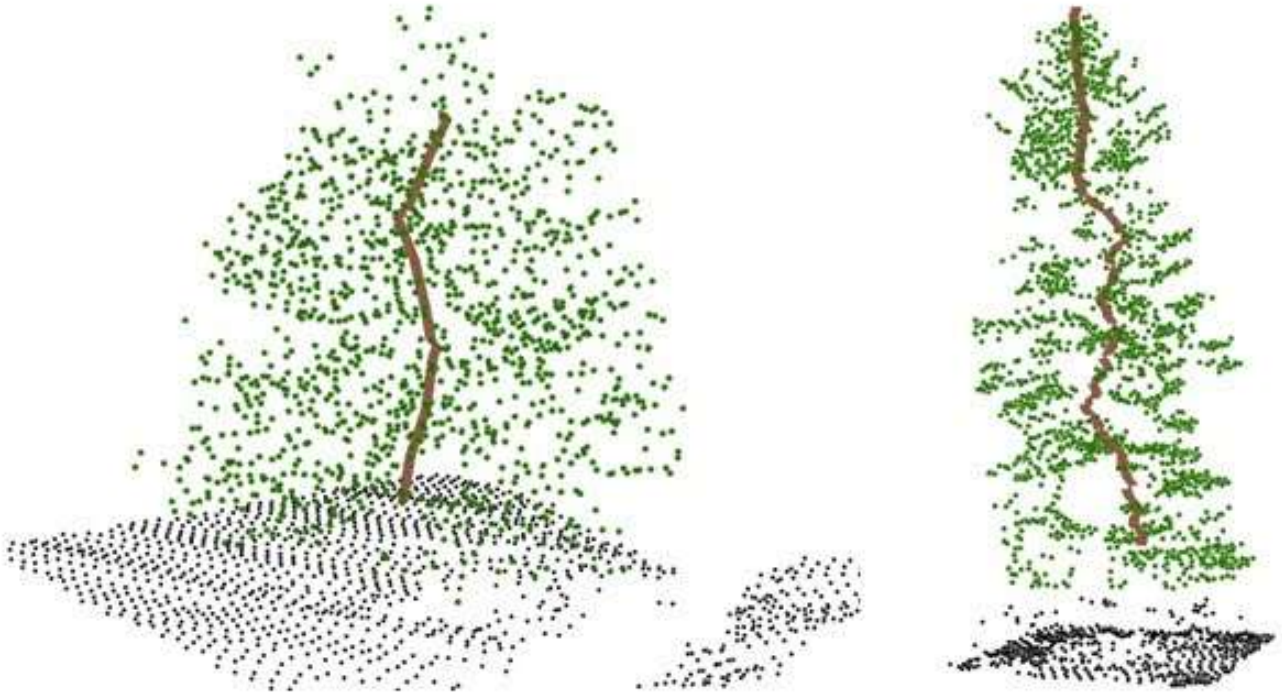
New Approaches - TLS

- Terrestrial laser scanning - aka LiDAR
- Specialised transmitter/receiver of laser pulses
- Glorified range finder



New Approaches - TLS

- Each pulse has an XYZ coordinate
- Calculate distance b/w points for height, diameter



New Approaches - TLS

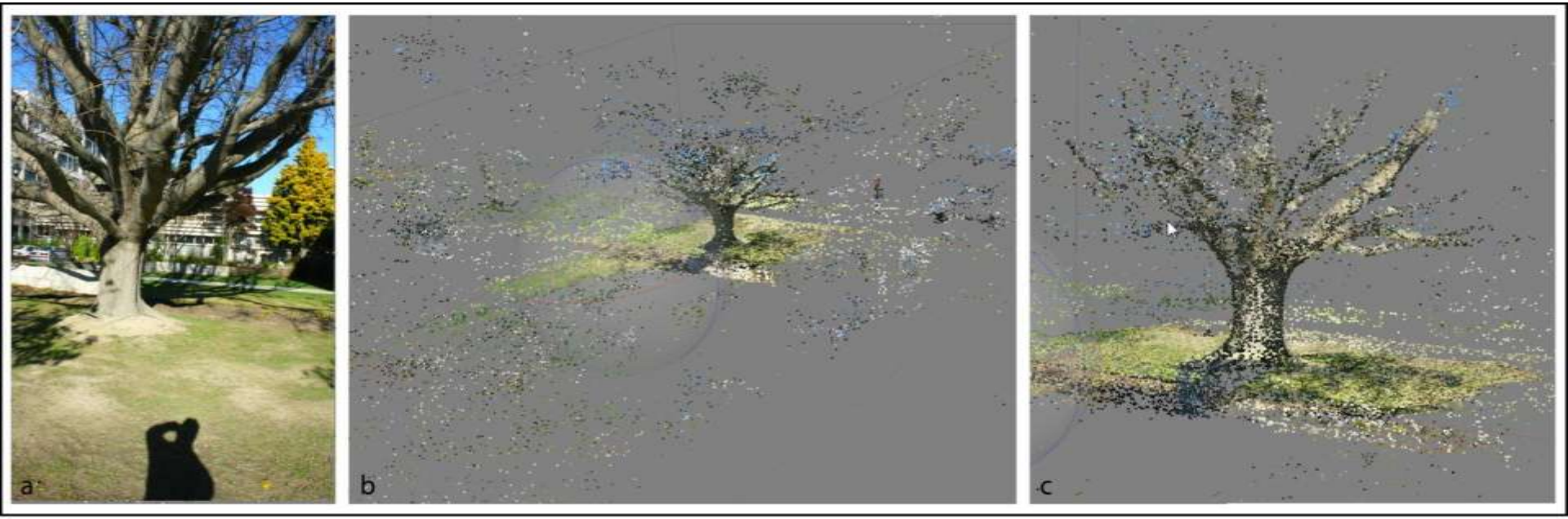
New Approaches - TLS

- Create an envelope covering the extent of the points
- Allows non-destructive estimates: stem, crown volume

TLS Street Tree Inventory

New Approaches - SfM

- Structure from Motion
- Used in video games, movies
- Create 3D models of objects



TLS and SfM – Accuracy Assessment

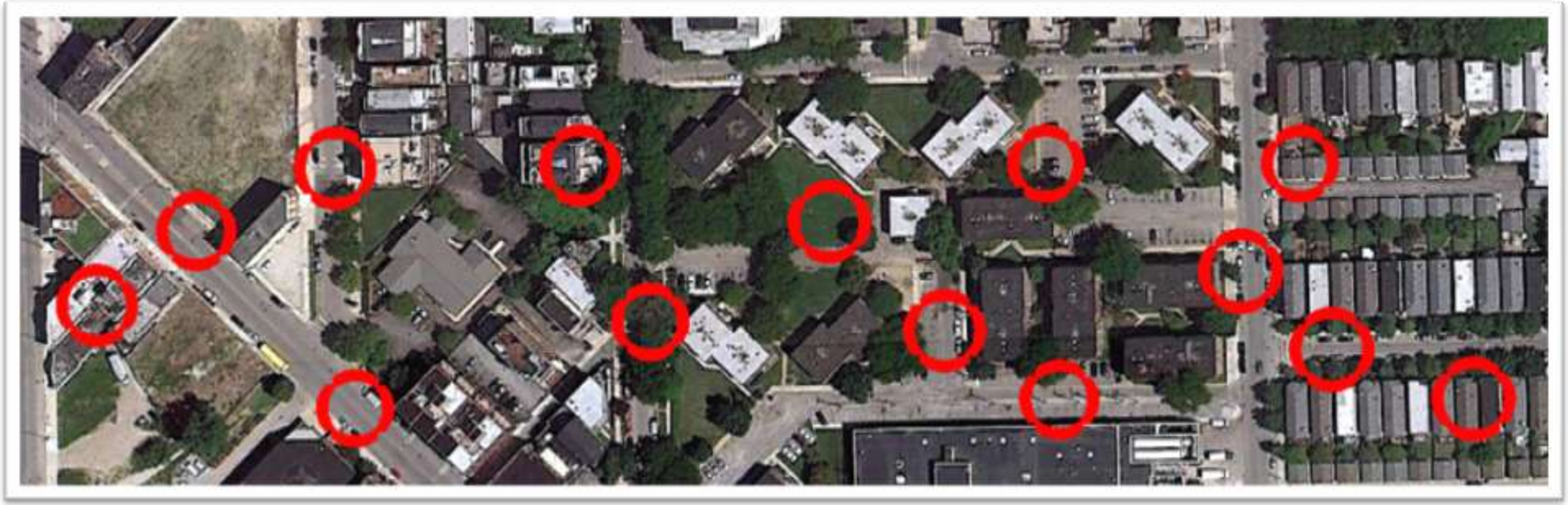
- Great technologies, but do they work?
  - TLS can produce highly accurate (> 95%) estimate of diameter
    - Height and volume are less accurate, but promising
  - SfM can produce highly accurate (> 95%) estimates of diameter and height
    - Volume is currently untested
- Will they replace traditional methods?

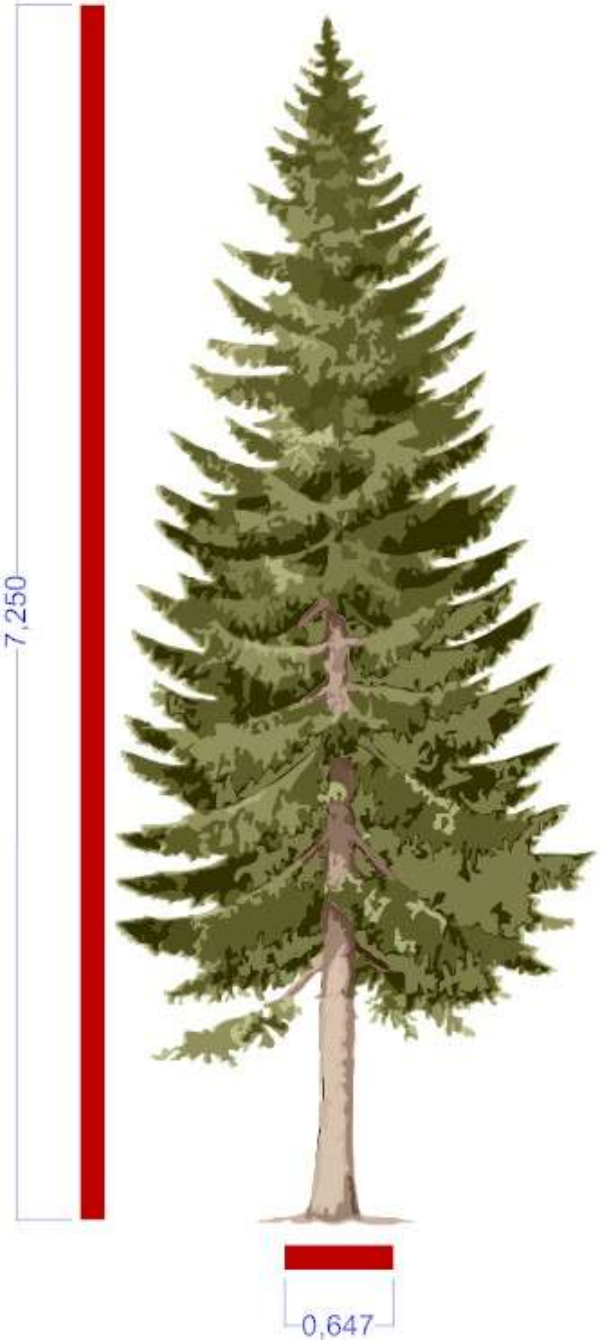
Why Measure the Urban Forest?

- Resource assessment
  - Budgeting, planning
- Species, size, and age-class distributions
  - Minimise problems associated with geriatric forests, pests
- Quantify Benefits:
  - Timber volume
  - Air pollution removal
  - Carbon sequestration and storage
  - Building energy use savings
  - Stormwater attenuation
  - Water quality

How do we measure the UF?

- Measure every tree?
  - How many trees in the UF?
- Sampling





i-Tree

Use easily measured attributes to estimate complex metrics

trees, size, species allow us to estimate leaf area and biomass

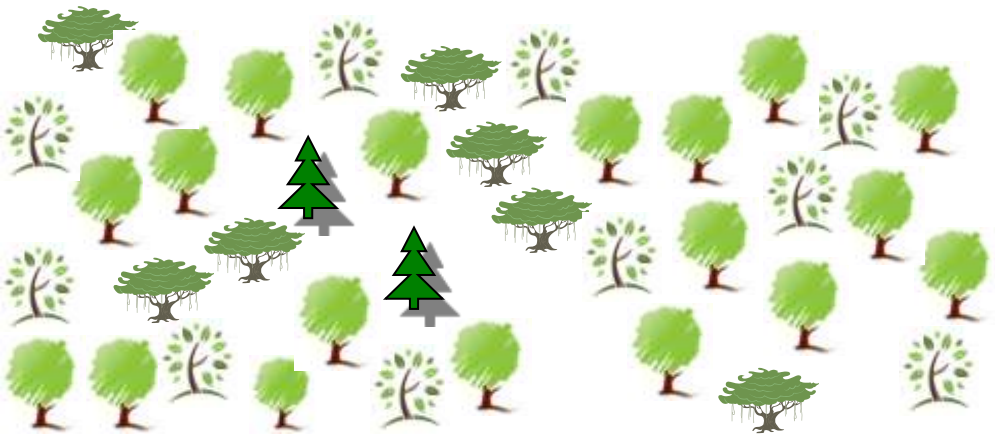
Use leaf area and biomass to estimate values

Case Study: Chicago Summary

Chicago Urban Forest Summary	
Feature	Measure
Number of trees	3,585,000
Tree cover	17.2%
Most common species	white ash, mulberry, green ash, tree-of-heaven
Percentage of trees < 6-inches diameter	61.2%
Pollution removal	888 tons/year ($6.4 million/year)
Carbon storage	716,000 tons ($14.8 million)
Carbon sequestration	25,200 tons/year ($521,000/year)
Building energy reduction	$360,000/year
Increased carbon emissions	-$25,000/year
Structural value	$2.3 billion
Ton – short ton (U.S.) (2,000 lbs)	

Problems with Current Techniques

- Require huge manual effort
  - expensive
- Sampling is always wrong
  - How do we know if we sampled enough?
  - How do we know our sample is representative?



	Population
	19
	9
	7
	2

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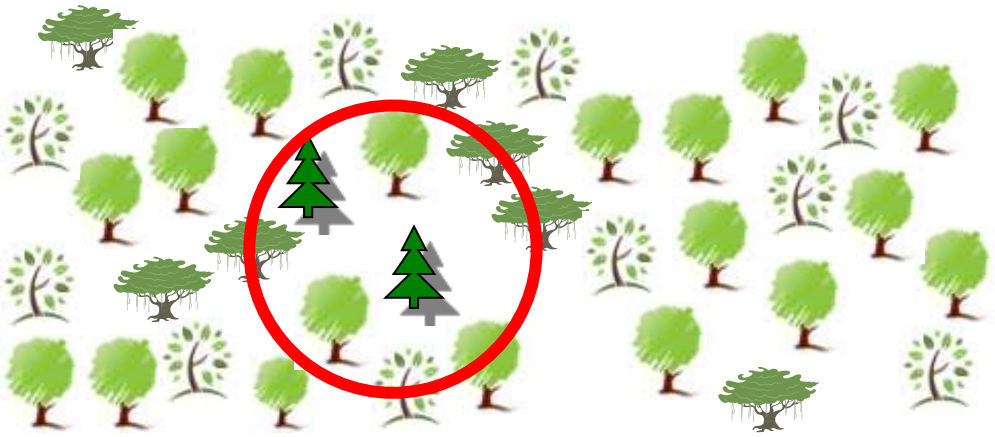

	Population	Sample 1
	19	3
	9	1
	7	3
	2	2

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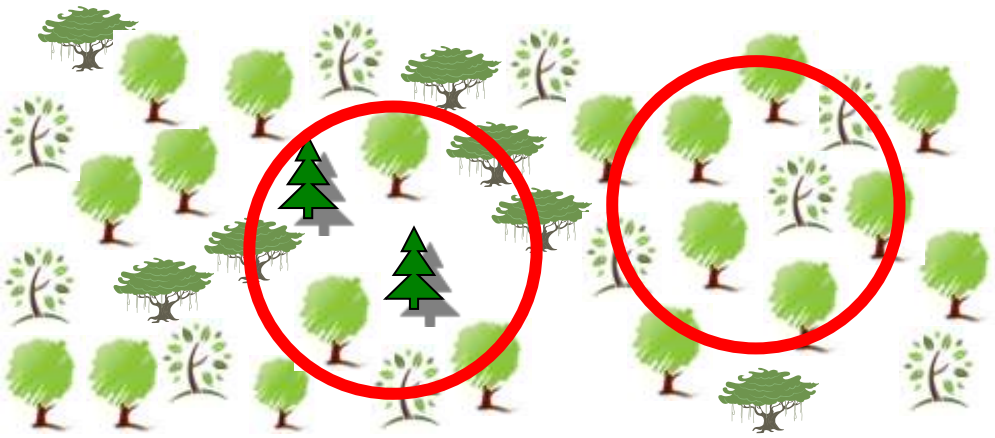
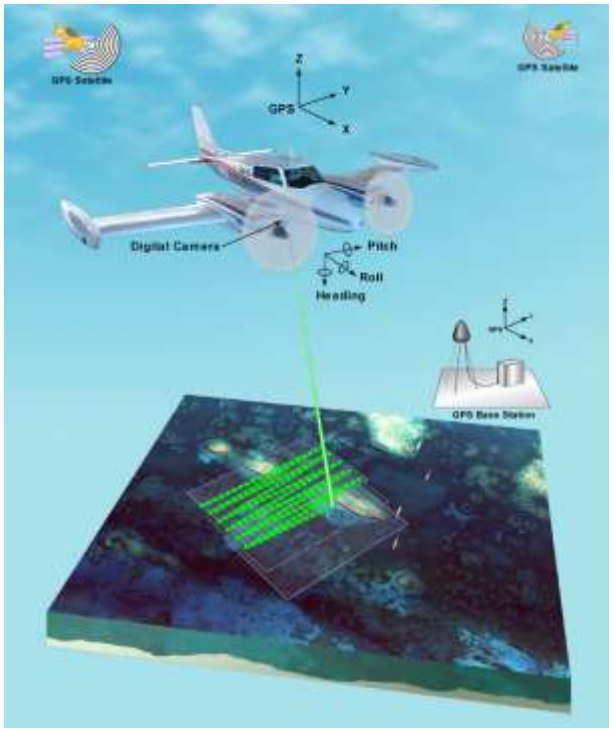
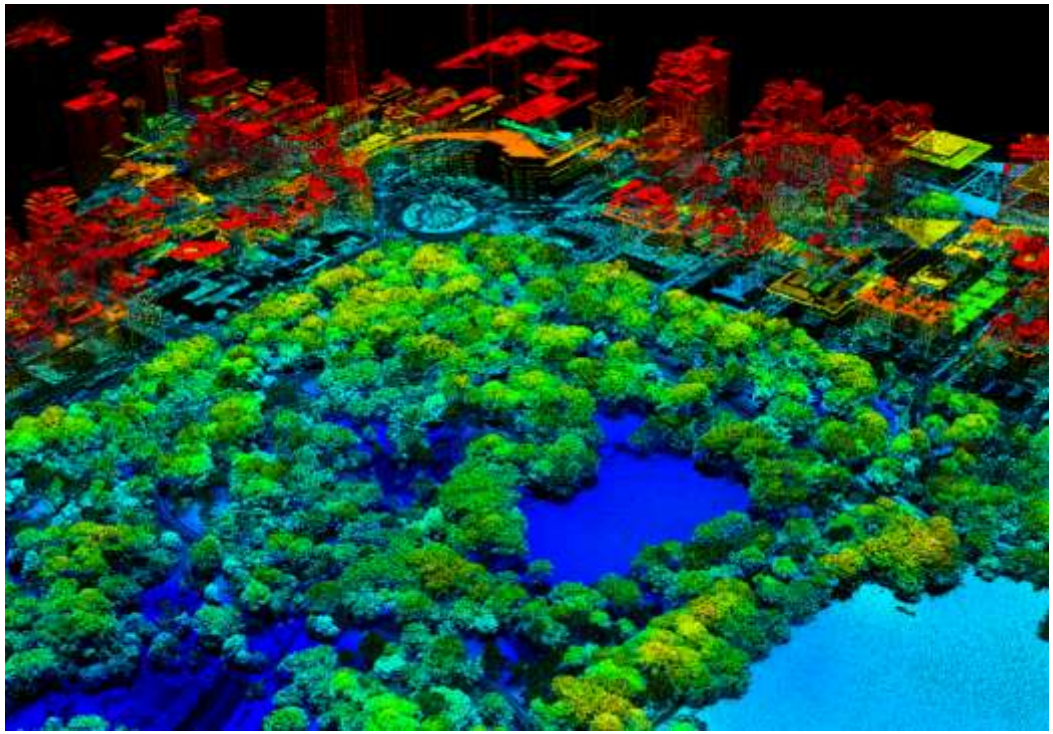


	Population	Sample 1	Sample 2
	19	3	10
	9	1	4
	7	3	3
	2	2	2

New Approaches - ALS

- Aerial laser scanning (aka LiDAR)
  - Uses laser pulses to map the surface of the earth
- Can give vertical structure of tree canopy





New Approaches – Satellite Imagery

- Multispectral
  - Easily identifies vegetation
  - Can ‘see’ stress

Image Classification

ALS and Satellite Imagery

- Can measure WHOLE urban forest
  - Not limited by sampling
  - Not limited by property boundaries
- Efficient measurements of tree canopy cover
- Tree counting, species differentiation, and 3D structural measurements are improving

The Digital Forest

- Traditional measurements are simple and trusted
- If applied incorrectly, high level of error
  - Can cause inaccuracy in resource assessment, budgeting, calculation of benefits
- New approaches are still emerging, but show great promise
- NZ could have world's first national urban forest map